New Aspects of a Lid-Removal Mechanism in the Onset of an Eruption Sequence that Produced a Large Solar Energetic Particle (SEP) Event (+L5 Comment)

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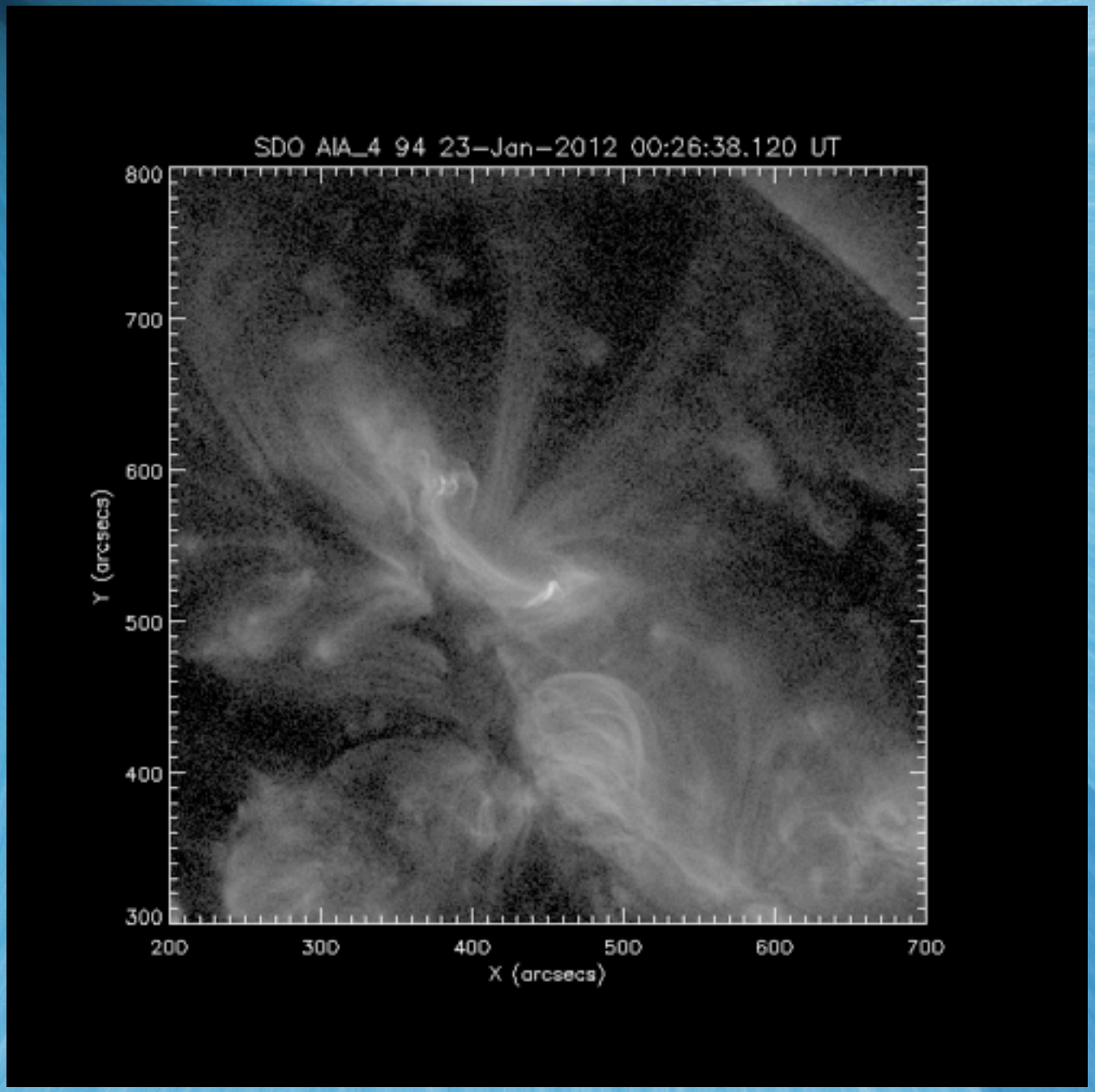
An Active Region Ejective Eruption

- Active region eruption of 2012 January 23.
- Ejective eruption.
- GOES class M8.7 flare.
- CME has ``complexities.'' Very fast: 2100 km/s.
- Results in strong Solar Energetic Particle (SEP) event. (1 MeV proton flux of $>10^3$ pfu for 43 hrs.)

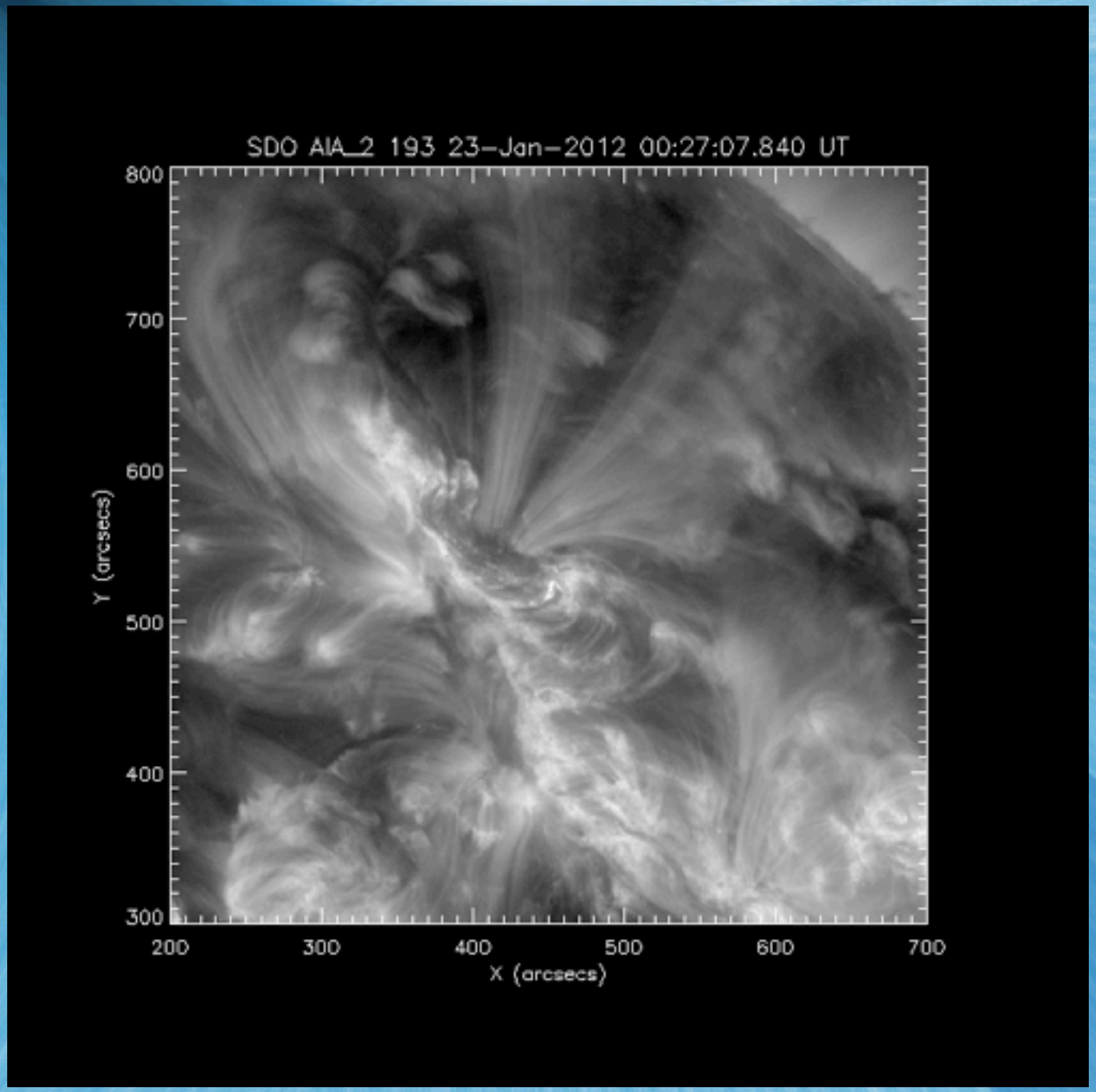
- Only ~1%---2% of all CMEs generate SEPs, so this event is "special."
- SEPs not the focus here. See Joshi et al. (2013). Also see Liu et al. (2013) for other interplanetary aspects.
- ("Lid removal" discussion to follow in a bit.)

Our Focus: Overview of the eruption onset: Eruption dynamics and magnetic topology

- AIA: Adequate time cadence (145 s) and high spatial resolution (0".6 pixels).
- SDO/HMI line-of-sight magnetograms.
- On-disk from SDO; limb event from STEREO A.
- SDO/AIA, various filters (304, 171, **193**, 211, 131, 335, **94** Ang).
- Two distinct eruptions ("two flux ropes," Li & Zhang 2013, Cheng et al. 2013); Eruption 1 and Eruption 2.
- Eruption 2 includes eruption of a filament.



A. Sterling, Dec 2014 L5, Boulder



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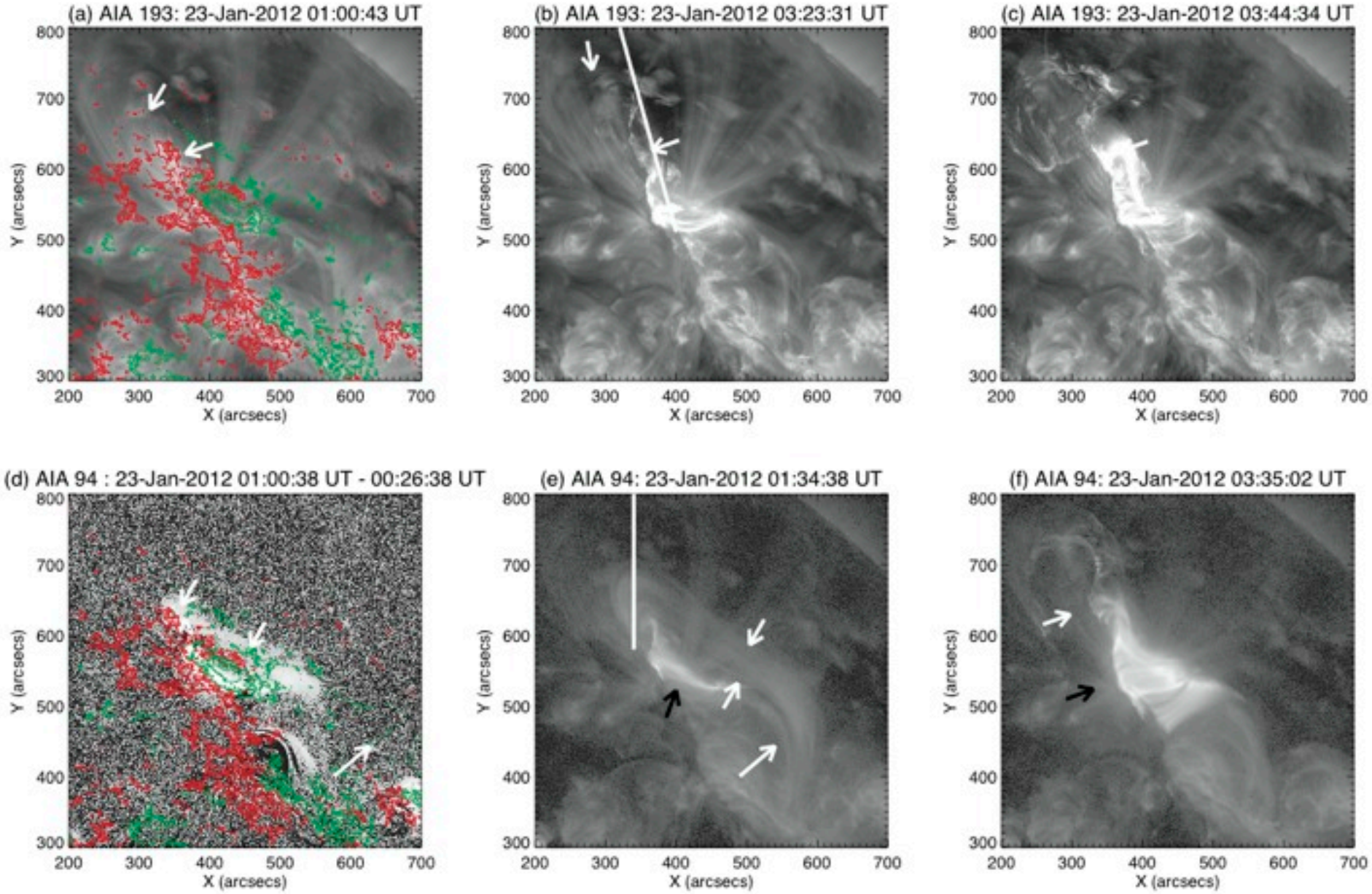
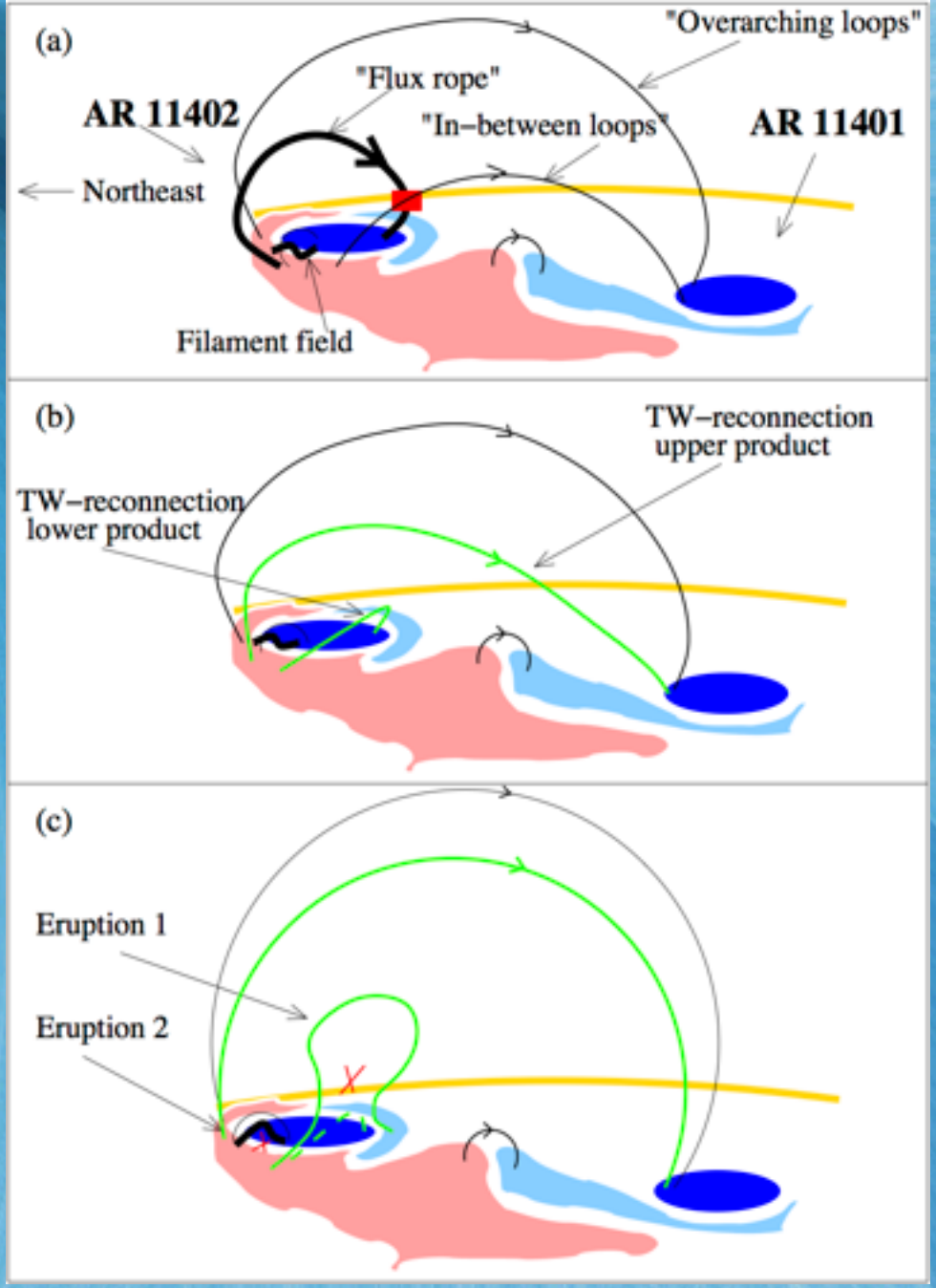
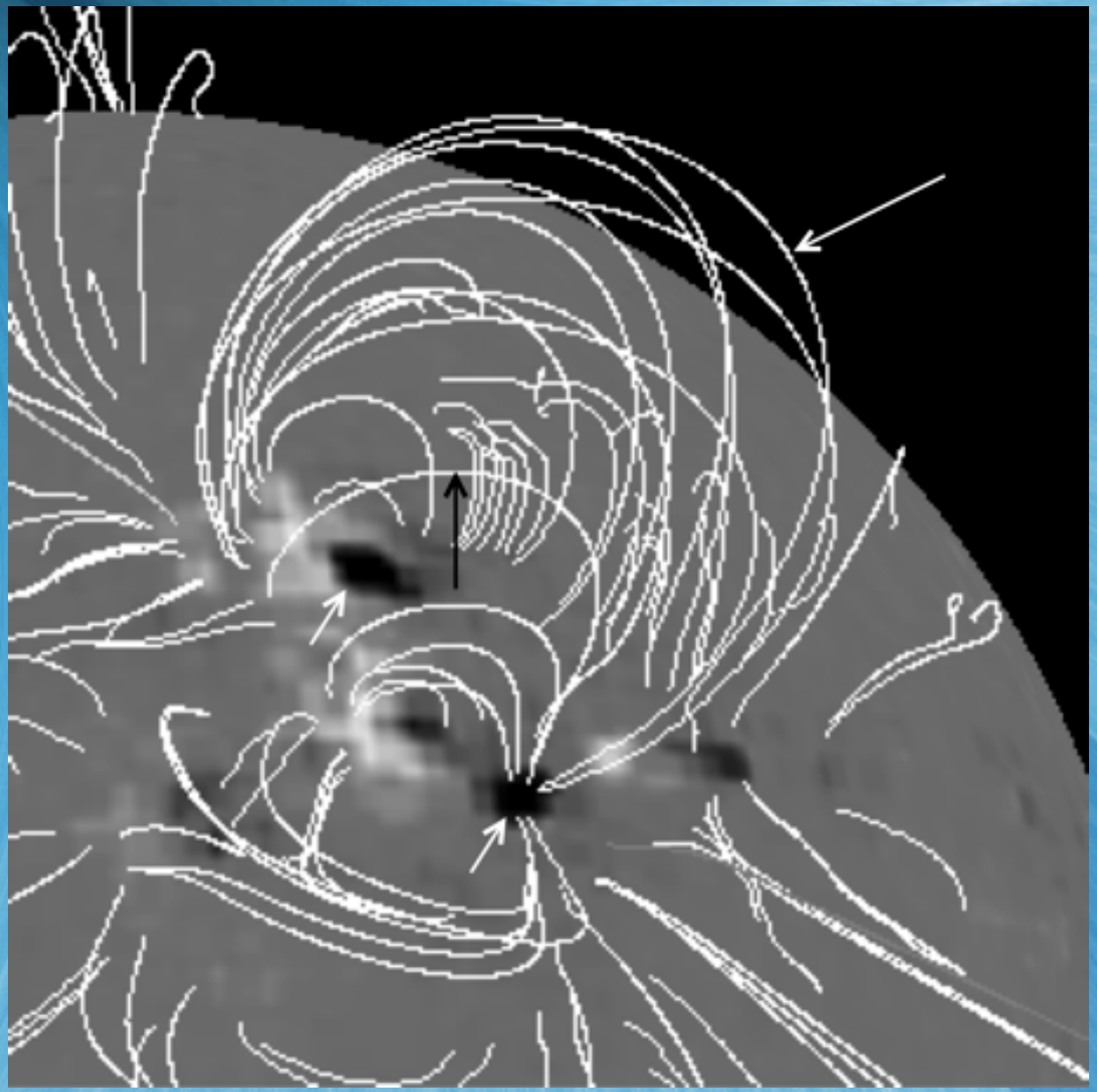
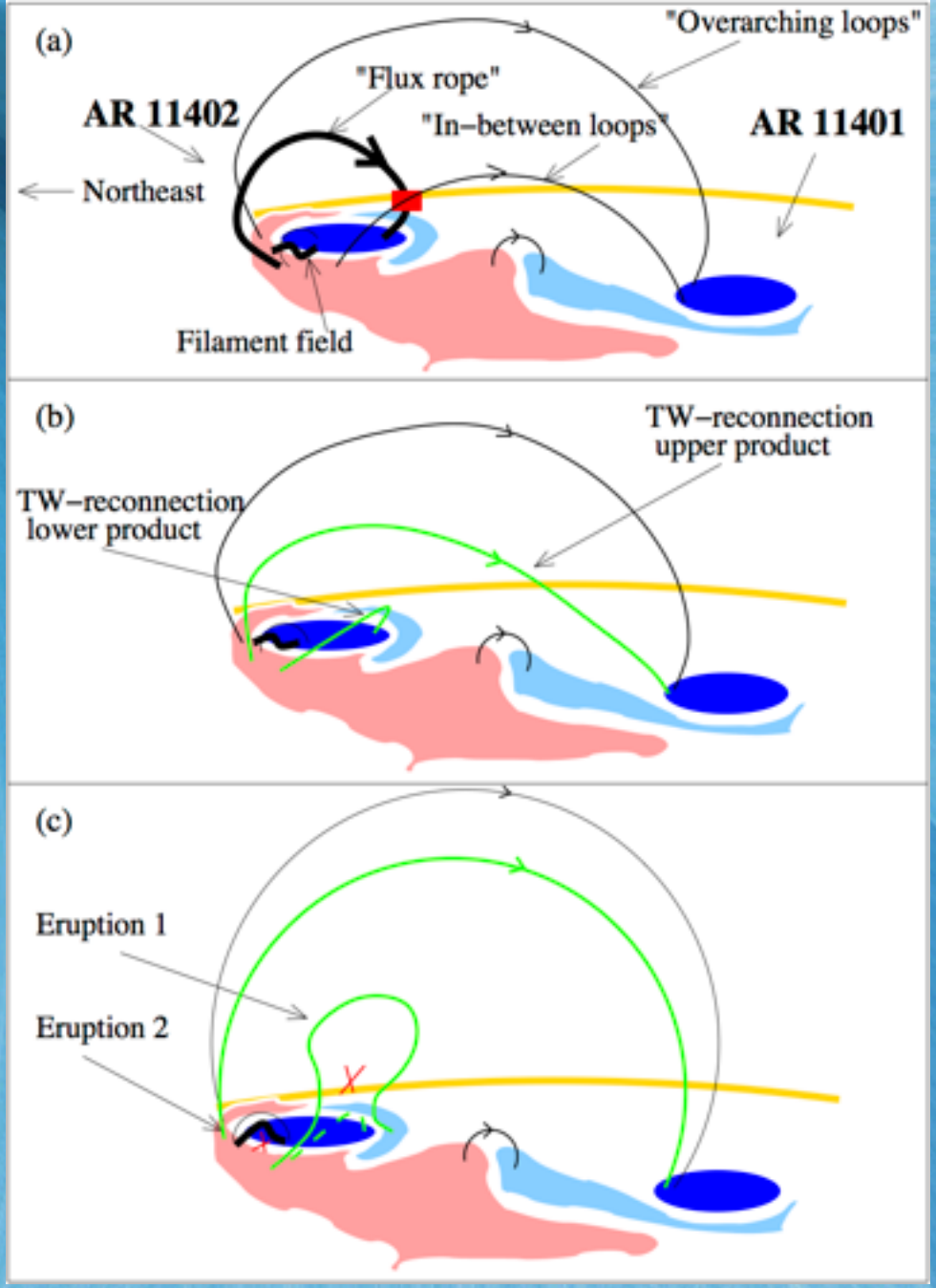

(a) AIA 193: 23-Jan-2012 01:00:43 UT
(b) AIA 193: 23-Jan-2012 03:23:31 UT
(c) AIA 193: 23-Jan-2012 03:44:34 UT
(d) AIA 94 : 23-Jan-2012 01:00:38 UT - 00:26:38 UT
(e) AIA 94: 23-Jan-2012 01:34:38 UT
(f) AIA 94: 23-Jan-2012 03:35:02 UT
Y (arcsecs)
X (arcsecs)
300
400
500
600
700
800
200


(a)
"Overarching loops"
"Flux rope"
AR 11402
"In–between loops"
AR 11401
Northeast
Filament field
(b)
TW–reconnection
upper product
TW–reconnection
lower product
(c)
Eruption 1
Eruption 2

PFSS Model (Schrijver & DeRosa 2003)

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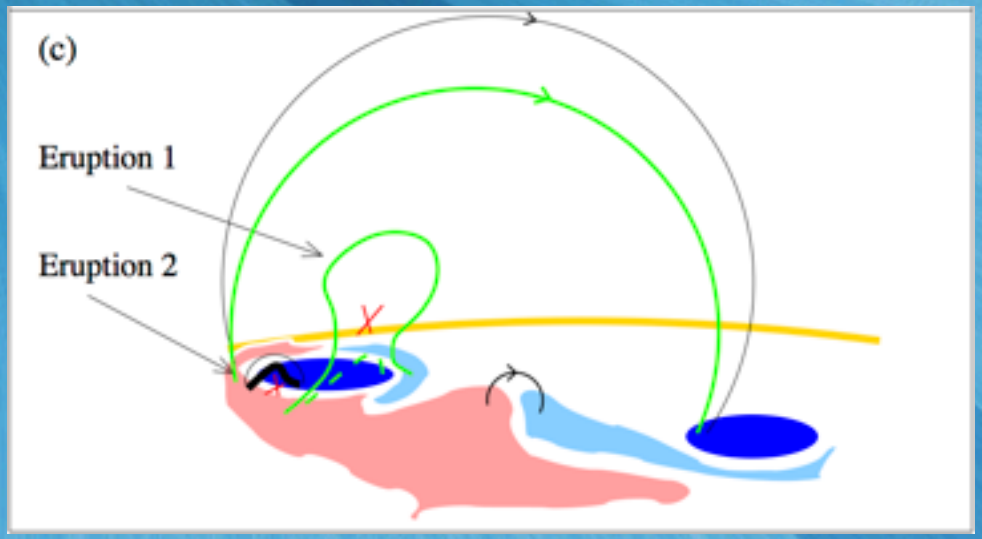
Eruption 1
Eruption 2

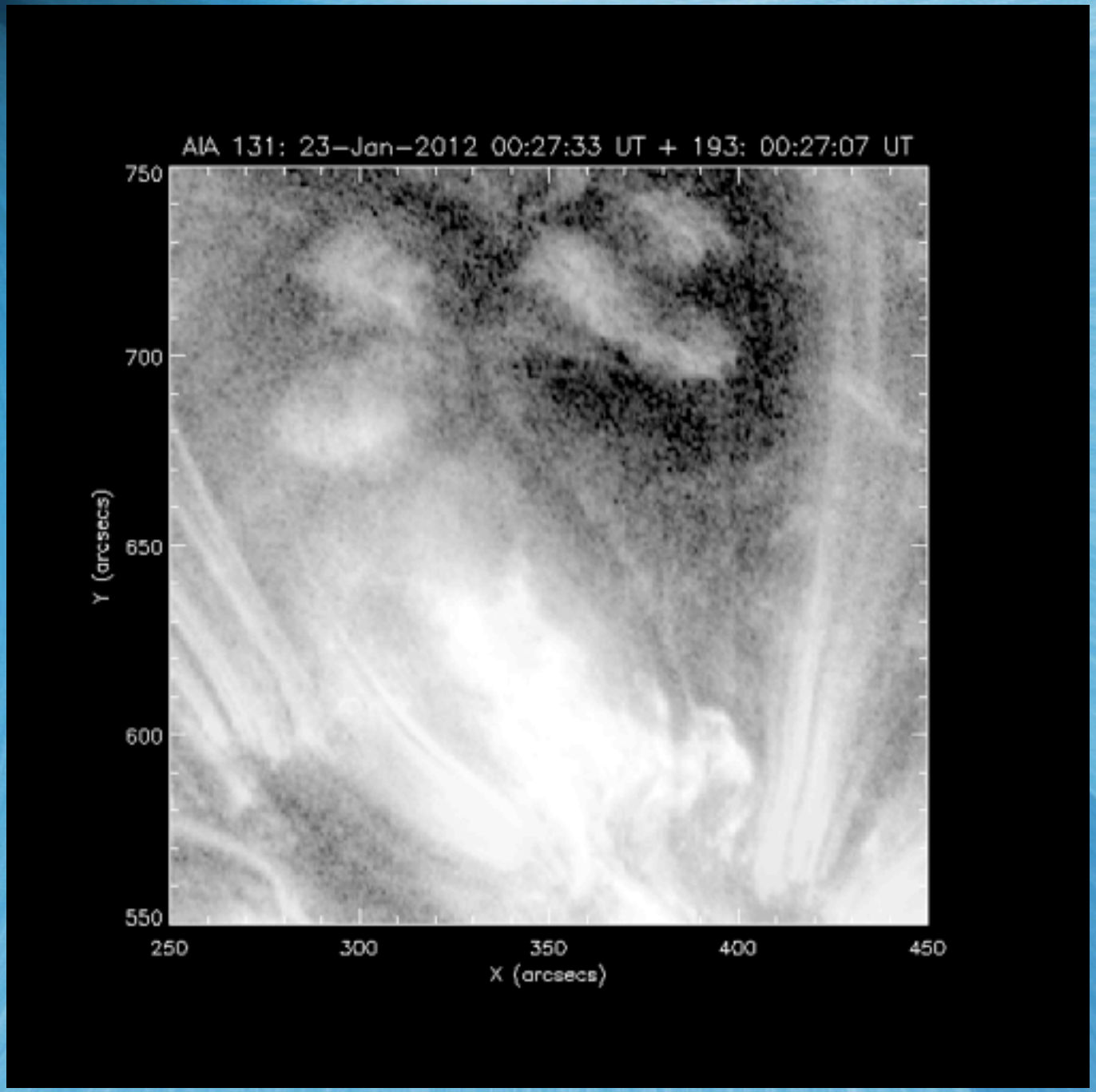
Eruption 2 Via "Lid Removal"

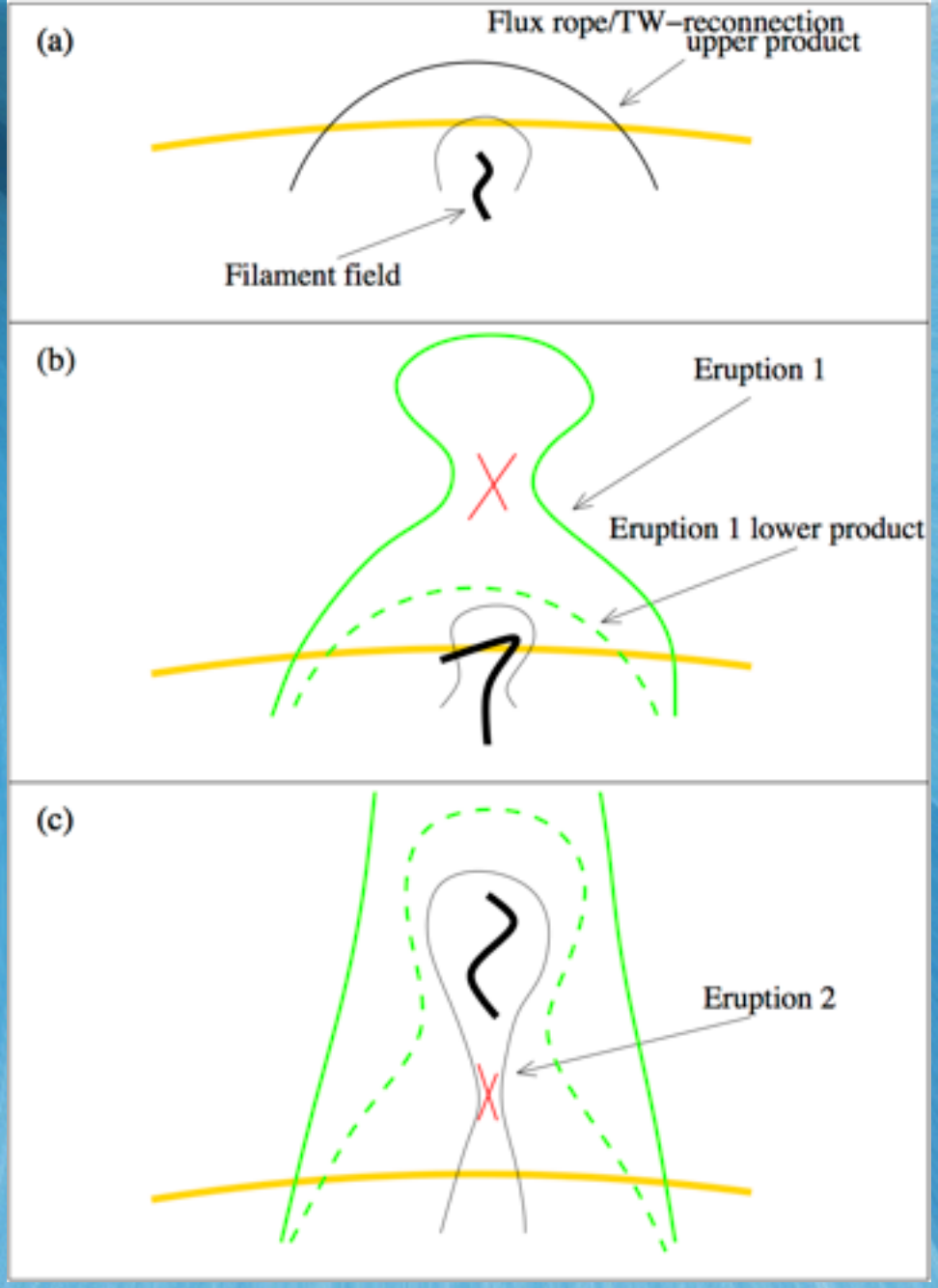
- Cheng et al. (2013) describe how Eruption 1 removes field above the Eruption 2 flux rope.
- They show B gradient with height is steep enough for Eruption 2 flux rope to be subject to torus instability, allowing its eruption. (Eruption due to ideal MHD instability.)
- We call their explanation for Eruption 2 (including filament) "lid removal."
- Fundamentally different from eruption-trigger mechanisms we have examined (e.g., tether cutting, breakout…).
- Similar however to other observations/descriptions (e.g., Schrijver & Title 2011, Török et al. 2011).

Can Lid Removal Work with Eruption 1 Flare Arcade?

- Standard flare model => Eruption 1 flare loops should form over filament arcade, perhaps preventing Eruption 2 ("confined eruption"). (S. Antiochos 2013, private comm.)



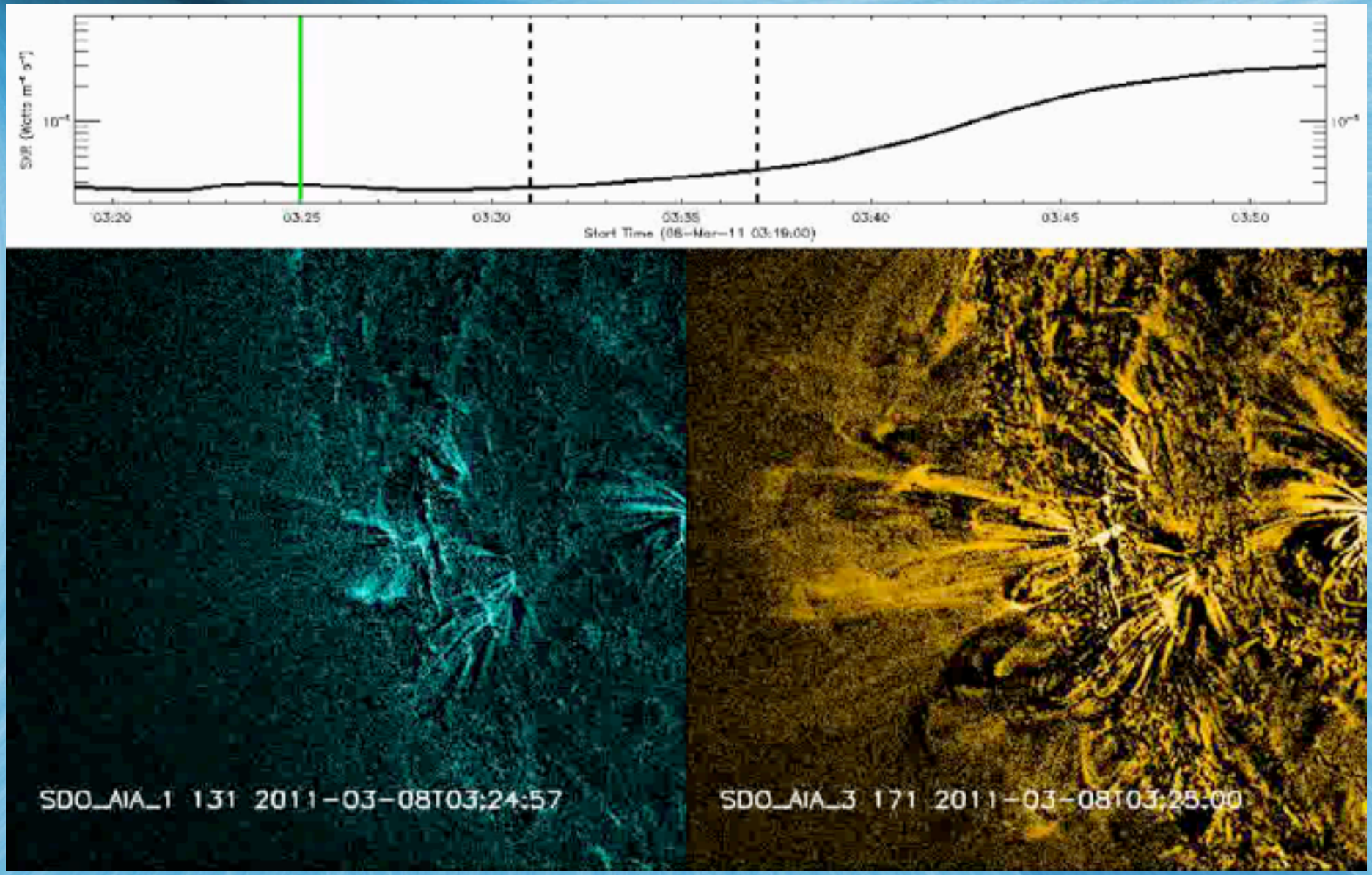

AIA 131: 23-Jan-2012 00:27:33 UT + 193: 00:27:07 UT
750
700
650
600
550
Y (arcsecs)
250
300
350
400
450
X (arcsecs)


(a)
Flux rope/TW–reconnection
upper product
Filament field
(b)
Eruption 1
Eruption 1 lower product
(c)
Eruption 2

Science Summary: 2012 Jan 23 Event

- Two eruptions, with first only seen in AIA hot channels.
- Eruption 1 field reconnects with neighboring region, ("tether-weakening reconnection," Moore et al. 1992).
- Eruption 1 removes field above filament arcade, leading to destabilization and onset of eruption 2;

  Lid Removal.
- Eruption 2 blows out Eruption 1 flare loops.
- Regarding SEPs: Double CMEs likely critical (e.g., Kahler 2001; Gopalswamy et al. 2002, 2003, 2004; Li et al. 2012). Effects on above points not yet known.
- Sterling et al. (2014) provide more details.



Zhang et al. (2012)

Important Points for L5 Mission

- Eruptions can "hide" in the hotter channels!
- Hot eruptions can be key to onset of violent eruptions, including SEP-producing eruptions.
- L5 EUV instruments should consider including at least one hot channel in its imaging arsenal.